A Nutrition Perspective – 1974

Prof. Dr. Fredric W. HILL

Department of Nutrition
University of California, Davis

The world is nutrition conscious as never before. One dimension is the reality of imminent starvation in drought-stricken countries. Another is the recognition that food reserves on a global basis are relatively small. Even in the most fortunate countries, there is concern about nutritional health, and the impact of intensive food production systems on our environment and the quality of life.

That we are able to comprehend the nutritional problems of our time is due to a very large extent to the achievements of nutrition scientists over the past fifty years, with major contributions by nutrition scientists who worked with domestic animals. The ultimate objective of all nutrition scientists is the betterment of human nutrition. I submit that experimental animal scientists make three contributions toward this goal: (1) by searching for new nutritional knowledge, they contribute to the establishment and elucidation of nutrition principles applicable generally to all animal life; (2) by applying these nutritional concepts to the nutrition of domestic animals, substantial and continuing improvement in productive efficiency has been achieved; (3) through the application of nutrition knowledge to the solution of problems in animal nutrition, models of experimental attack and problem-solving are developed which lead the way to similar research and problem-solving in human nutrition.

The past fifty years of nutrition research, the period commemorated by your meeting here, has produced truly remarkable progress both in the discovery and in the application of nutrition information and concepts. This period has included

- elucidation of the vitamins
- discovery of most of the trace mineral elements now known to be essential
- proof of the amino acid basis of protein nutrition
- elucidation of the distinctive nutritional properties of fats
- establishment of quantitative nutrient requirements for many species, which serve as the basis for nutritionally adequate diets
- refinement of knowledge of the energy relationships in metabolism and the useful energy of foods and feeding materials.

The application of the increasing fund of nutrition knowledge to the feeding of domestic animals has been rapid, with striking improvements in the efficiency of production of animal source foods. Equally remarkable has been the development of synthetic or specialized sources of vitamins and minerals needed for supplementation of animal diets, which has two important consequences. First, the benefits of this research can be incorporated in animal rations through such supplements for a small fraction of the total cost of the feeding program; in rations for chickens and turkeys which require relatively high supplementation levels, the vitamins and minerals currently represent less than 2% of the cost of the total ration. Further, and equally important, the major constituents of the diet can be chosen to provide the necessary energy and protein components, with great flexibility because their micronutrient contributions are not limiting. This is not to say that all of the informa-

HILL

tion as to the identity, requirements for, and interrelationships of the essential nutrients been completed - far from it, but we have a substantial and systematic body of knowledge of great value.

An area of increasing importance is the use of synthetic amino acids to supplement and extend the protein in rations for non-ruminant domestic animals. In recent years the fluctuating supplies of major protein feeding resources have created problems which synthetic amino acids were especially useful in meeting. As you know, the world leadership in the production of synthetic amino acids has been provided by Japan.

The scientific breakthroughs in animal nutrition have made possible similar advances in understanding and quantifying human nutrition, but with a significant time lag. The major attention of the world is on human protein and energy requirements, and these are, of course, of primary concern. In due course, we can foresee that the systematic use of micronutrient supplements can provide the same kind of flexibility in insuring nutritionally adequate food mixtures for humans as we are now able to achieve in the simpler nutritional applications for domestic animals.

Protein is in the spotlight in many ways today. Among the most tragic consequences of human malnutrition is the permanent damage that can be produced by protein deficiency in young children during the highly vulnerable period up to about two years of age. The basic reasons for the vulnerability of young children have been elucidated by research showing that protein deficiency can exert two effects (1). There is a stage in early development for each organ and system during which it grows rapidly in number of cells; in later development, growth occurs by increase in cell size. If protein deficiency occurs while a particular organ or system is growing in cell number, a permanent reduction in the number of cells occur. Subsequent improvement of the diet will not restore the normal number of cells and size of organ. The effect of protein deficiency in later development is to retard growth in cell size, and this effect can be remedied by improved nutrition subsequently. It is of critical significance, therefore, to design nutrition programs so that they fully meet the protein needs at the most vulnerable times. These occur during pregnancy and lactation of the mother, during which the unborn or young infant can be affected, and the early post-weaning growth of the young child.

Recognition that protein malnutrition occurs in children in many parts of the world has focused attention of international planners on protein as a critical need in the world food supply. While it is true that food resources of some countries need upgrading in protein and other essential nutrients, it appears that the magnitude of the regional and global needs for protein have been overestimated and overemphasized. New research and the reassessment of previous information has led to estimates of human protein requirements by an Expert Committee of the Food and Agriculture Organization and the World Health Organization (2) which differ substantially from previous estimates (3). The requirements of adults and older children have been reduced by 20% or more, while the requirements for younger children were increased slightly. The current and earlier estimates are summarized in Table 1.

The current estimates of human protein requirements have been compared to the food protein supplies of various regions of the world for the year 1970, taking into account the nutritional quality of the protein supplies (4), and the comparisons are summarized in Table 2. All regions of the world, and the world as a whole, have per capita food protein consumption levels which substantially exceed the estimated safe levels of intake needed to meet the requirements. In the world as a whole, food protein consumption was 73% above requirement, while the developed regions consumed more than double the requirement. In developing regions, with more limited resources, average food protein consumption exceeded requirements by more than 40 %. In contrast, the estimated

A Nutrition Perspective - 1974

consumption of food energy barely equalled the requirements for the world as a whole, and was below requirements for most developing regions.

Table 1. Estimated human requirements¹ for protein

Age and Sex	1965 Estimates		1973 Estimates	
	g/kg day	g/day	g/kg day	g/day
Children, 1 - 3 yrs	1.06	13	1.19	16
Children, 4 - 6	.97	17	1.01	20
Children, 7 - 9	.92	25	.88	25
Children, 10 - 12	.86	30	.81	30
Males, 13 - 15	.84	41	.72	37
Females, 13 - 15	.84	39	.63	31
Males, 16 - 19	.77	49	.60	38
Females, 16 - 19	.77	42	.55	30
Adult Men	.71	46	.57	37
Adult Women	.71	39	.52	29
Late Pregnancy, add		+ 6		+ 9
Lactation, add		+15		+17

¹ Requirements expressed as reference protein (1965) and as egg or milk protein (1973), and include provision for individual variability in order to provide a safe level of intake which will cover the needs of the great majority of individuals.

Table 2. Per capita daily energy and protein requirements and 1970 levels of consumption

	Per capita daily requirements ¹		Percentage of requirements - 1970 consumption	
	Energy, kcal	Proteins, ² grams	Energy %	Proteins %
WORLD	2,385	38.7	101	173
DEVELOPED REGIONS	2,560	39.5	121	229
Developed market economies	2,555	39.2	119	228
Eastern Europe and the U.S.S.R.	2,570	40.0	124	232
DEVELOPING REGIONS	2,284	38.4	96	147
Asia and Far East ³	2,223	36.6	93	141
Africa	2,335	41.5	93	141
Latin America	2,383	37.7	106	172
Near East	2,456	45.5	97	147
ASIAN CENTRALLY PLANNED ECONOMIES	2,355	38.3	88	153

¹ FAO estimated average requirements (1973), weighted for age and size distribution of populations.

² Provisional data expressed in local proteins.

³ Excluding Asian centrally planned countries.

Because of some inevitable maldistribution and wastage, an excess of supply over requirements is necessary to provide adequately for a population, so the marginal supply of total food, expressed here as energy, represents a critical problem. Recognizing that the utilization of protein as well as other nutrients is impaired by dietary energy deficiency, it is evident that food energy shortage is

HILL

the world nutrition problem of first significance. While the goal of fully adequate nutrition will require concurrent development of resources and methods to supply all the essential nutrients, the first order of priority must be given to ensuring an adequate total food (energy) supply. With strong programs in nutrition education and enlightened food policies, protein malnutrition problems can be met in most situations by current resources. Meeting future needs is mainly a matter of expanding production of the existing pattern of foods of a region. In the developed regions, significant reduction in the per capita consumption of protein-rich foods and their replacement by cereal products or other staples is clearly a nutritionally feasible strategy to meet the needs of expanding populations.

The agricultural production systems of the industrialized countries, exemplified particularly by the United States, have achieved high efficiency of production relative to labor input and land area. The abundance produced by the industrialized agriculture has made it possible to use a large amount of crop resources for animal production. The industrialized food production systems are characterized by mechanization and a large input of industrial power (fuel energy), in exchange for reduced human labor input. The intensive production systems also utilize high levels of nitrogen fertilization of crops. Recent analyses have indicated that at current rates of nitrogen fertilization the largest single energy input cost in corn production is represented by the nitrogen fertilizer (5). In terms of energy input, the efficiency of corn production in the United States has declined in the past 30 years, while yield per acre more than doubled and labor per acre was decreased more than 60 % (5).

The new era of limited supplies and markedly increased cost of fuel energy sources has focused attention on energy input as a limiting and costly factor in the production and utilization of foods, particularly in the primary food-exporting countries. The impact of the change in energy cost on the strategy of meeting world and regional food needs will be great. Because nitrogen fertilization is an energy-expensive component of the food production system, costs of food proteins may be particularly affected. It appears likely that the relative cost of proteins, and in particular proteins from animal source foods, will rise. The place of protein as such and the nutritional contributions of protein-rich foods must be evaluated in terms of real human needs and the new cost relationships.

One could interpret these facts as portending a gloomy future for the animal production industries. I do not share this interpretation, and I think the value of animal agriculture should not be minimized. The competition between people and food-producing animals for limited food crop resources needs to be understood, of course. In any economy, there are land and crop resources that cannot be used effectively for feeding people; in addition, there are wastes, by-products, and damaged materials which can form the basis of an efficient animal production component of the food system. Using improved animal stocks and modern feeding and management methods, the productive efficiency of the meat, milk, and egg industries have been progressively improved. Of all our food resources, animal products are the most versatile as sources of essential nutrients and the most readily accepted by most people. When one adds to this the significant function of food producing animals to act as a barrier between humans and a great variety of natural and other toxicants in our food environment, their role is multiply beneficial indeed.

To consider only the protein requirements of humans in relation to decision-making as to total protein production and the role of animal industries is an oversimplification. Certainly, animal source foods have served historically to provide many of the vitamin and mineral requirements of humans. Until we are ready to make much more intensive application of nutritional knowledge toward the development of nutritionally versatile human foods, in a manner analogous to the application of nutritional advances by the animal industries, animal source foods will continue to occupy a special place in the nutrition of humans.

A Nutrition Perspective - 1974

The importance of nutrition and nutrition decision-making in the years ahead can hardly be overstated. As a field of experimental biology, nutrition research is pursued at four levels of organization, each of which has made and will make essential contributions. At the molecular level, the identity and functions of each of the essential nutrients must be established. That this is a continuing process is well illustrated by the recent finding that what we have known as vitamin D for nearly fifty years is a precursor to the active substance made by the body for the control of the absorption and deposition of calcifying elements (6). At the level of cells and organs, the classical physiology, the interrelation of the major nutrients, the control of protein synthesis, lipogenesis and gluconeogenesis, and the regulation of homeostasis all need elucidation toward the goal of defining optimum nutrition. At the whole animal level, the definition of nutrient requirements, the factors involved in the regulation of food intake and food selection, and the interactions between environment and nutrition come into play and have direct impact on the animal production industry. At the population level, behavior-nutrition relationships come into play which are clearly not predictable from knowledge of animals as individuals.

The perspective in which animal scientists as individuals or as a group view the characteristics of the biological systems in which they work tends to become fixed by our training and experience, and it is all too easy to close our minds to novel possibilities. For example, we regard the characteristics of cereal grains to include poor protein quality due mainly to lysine deficiency. The scientific breakthrough showing the genetic control of lysine content of corn protein has opened new concepts of nutritional improvement of food crops (7). We regard the pattern of nutritional requirement of an animal species as characteristic and relatively fixed. The demonstration that the requirement of chickens for an essential amino acid, arginine, differs markedly between lines selected for quite different traits opens new concepts of breeding for nutritional efficiency (8). We regard the composition of milk fat and body fats of ruminant animals as a fixed characteristic governed by rumen physiology. The breakthrough of "protecting" dietary lipids from hydrogenation in the rumen by formaldehyde treatment of associated proteins has opened the possibility of modifying the food fats of ruminant origin to characteristics which may have advantages for the consumer (9). Cattle and sheep now have the capability of reflecting the composition of their dietary fats in the composition of body and milk fats in a manner similar to the modifications possible with pigs and poultry. The stormy controversy about the relationship between dietary fats, cholesterol and heart disease may acquire new dimensions. Furthermore, the "protection" concept may also have important applications to the amino acid nutrition of ruminants.

These examples remind us that we should not regard present limitations of resources and knowledge to close our minds to new possibilities. At each level of integration in biological research we must be alert to advances at all levels, with the view of applying them to the necessary function of nutrition decision-making.

HILL

References

- 1) WINICK, M., and A. NOBLE. Cellular response in rats during malnutrition at various ages. *J. Nutrition* **89**: 300-306 (1966).
- 2) FAO/WHO Expert Committee. Energy and protein requirements. FAO Nutrition Meetings Report Series No. **52** (1973).
- 3) FAO/WHO Expert Group. Protein requirements. FAO Nutrition Meetings Reports No. **37** (1965).
- 4) The State of Food and Agriculture 1972. Food and Agriculture Organization of the United Nations, p. 24 (1972).
- 5) PIMENTEL, D., L. E. HURD, A. C. BELLOTTI, M. J. FORSTER, I. N. OKA, O. D. SCHOLLES and R. J. WHITMAN. Food production and the energy crisis. *Science* **182**: 443-449 (1973).
STEINHART, J. S., and C. E. STEINHART. Energy use in the U. S. food system. *Science* **184**: 307-316 (1974).
- 6) HOLICK, M. F., H. K. SCHNOES and H. F. DE LUCA. Identification of 1, 25-dihydroxycholecalciferol, a form of vitamin D₃ metabolically active in the intestine. *Proc. Nat. Acad. Sci.* **68**: 803 (1971).
- 7) MERTZ, E. T., L. S. BATES and O. E. NELSON. Mutant gene that changes protein composition and increases lysine content of maize endosperm. *Science* **145**: 279 (1964).
- 8) NESHEIM, M. C. and F. B. HUTT. Genetic differences among White Leghorn chicks in requirements of arginine. *Science* **137**: 691 (1962).
- 9) COOK, L. J., T. W. SCOTT, G. J. FAICHNEY and H. L. DAVIES. Fatty acid interrelationships in plasma, liver, muscle and adipose tissues of cattle fed safflower oil protected from ruminal hydrogenation. *Lipids* **7**: 83-89 (1972).
DINIUS, D. A., R. R. OLTJEN, C. K. LYON, G. O. KOHLER and H. G. WALKER, Jr. Utilization of a formaldehyde treated casein-safflower oil complex by growing and finishing steers. *J. Animal Science* **39**: 124-133 (1974).